The Value of Multi-Shot Echoplanar MR Imaging in the Diagnosis of Focal Hepatic Lesions: Comparison with Other Standard MR Imagings

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Won Hong Kim, M.D., Chang Hae Suh, M.D.

Purpose: To determine the diagnostic value of multi-shot echo-planar MR imaging (EPI) in focal hepatic lesions by quantitatively comparing this with other standard MR sequences such as FSE (fast spin echo) T2WI, SE (spin echo) T1WI with and without Gd enhancement, FMPSPGR (fast multiplanar spoiled GRASS) with and without Gd enhancement.

Materials and Methods: Seventeen patients with 18 focal hepatic lesions were retrospectively reviewed by two abdominal radiologists. The pathological or clinical results of hepatic lesions were nine cases of hemangioma, four of hepatocellular carcinoma, one of peripheral cholangiocarcinoma, one of simple cyst, and of hemangioma. By dividing the data acquisition period into eight interleaved segments, multi-shot EPI images were obtained. This T2W spin echo eight-shot EPIs of the liver in one 18 second breath hold was compared with other pulse sequences. The focus of review were lesion detectability and characterization. For the former, SNR (signal to noise ratio) of the liver and CNR (contrast to noise ratio) of the lesion to the liver were calculated; to evaluate the latter, a separate calculation of lesion to liver CNR for each solid and nonsolid lesion group was performed.

Results: Among six pulse sequences, multi-shot EPI provided the poorest liver SNR (p < .01). With regard to lesion to liver CNR, EPI was superior to FMPSPGR, SE, and Gd SE, but inferior to FSE, Gd FMPSPGR (p < .01). For nonsolid lesions (hemangioma, cyst), EPI provided higher liver CNR than FMPSPGR, SE, or Gd-SE, but one that was poorer than that provided by FSE and Gd-FMPSPGR (p < .05). Among six pulse sequences, there was no statistically significant difference in lesion to liver CNR in solid lesions. In the evaluation of liver to lesion CNR, multi-shot EPI was always inferior to FSE.

Conclusion: We concluded that with regard to sensitivity and susceptibility, multi-shot EPI is inferior to T2W FSE. For SNR, EPI was the least satisfactory, though with the exception of FSE, EPI provided a higher or comparable CNR than other pulse sequences, and this made lesion depiction easy, especially in nonsolid lesions. It was, however, difficult to characterize lesions by using EPI alone to determine whether a lesion was solid or nonsolid.

Index words: Liver neoplasms, MR
Magnetic resonance(MR), Comparative studies
Magnetic resonance(MR), echoplanar

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Echoplanar MR imaging (EPI) is a fast imaging technique that allows collection of all the data required to reconstruct an image in an interval as short as the duration of a single readout period (about 30 - 100msec) (1). With image acquisition times in the order of 1/10 of a second or less, EPI represents the fastest clinically useful imaging technique(1). Although EPI may be important in the examination of organs in which artifacts due to gross physiologic motion are present(2), most clinical application is limited by poor imaging quality (3) as well as the apparent need for a costly high-power gradient system(4). In the abdomen, problems associated with poor imaging quality arise from the susceptibility artifact caused by air containing bowel and lung, and the chemical shift artifact caused by incomplete fat saturation. The purpose of this study was to quantitatively compare multi-shot EPI with other standard MR imaging modalities including conventional fast spin echo(FSE), spin echo(SE), fast multiplanar spoiled gradient echo(FMSPGR), gadolinium enhanced spin echo(Gd-SE), and gadolinium enhanced fast multiplanar spoiled gradient echo(Gd-FMSPGR).

Materials and Methods

**EPI MR imaging**

MR imaging was performed on a 1.5 T superconducting scanner(Signa; General Electric, Milwaukee, Wis). The system provides a maximum gradient strength of 23mT/m, with a peak slew rate of 77mT/mmsec and rise time of 300 μsec. Eight excitation images providing higher spatial resolution were obtained using a spin-echo pulse sequence with a data matrix of 256 (phase) X 128(frequency) providing a plane resolution of 1.2 X 1.8mm for a 32 X 24cm(phase X frequency) field of view (n=7) and 1.4 X 2.1mm for 37 X 27 cm (n=4). Delay between excitation was set at 2 sec and effective TR values of 2000 msec were obtained; the corresponding effective TE values were 60msec and 40 msec. We defined scan time as the time taken to acquire a complete set of axial abdominal images with a given TE. With an 18 sec scan time, EPI was performed in the multi-slice mode, and a predesignated number of images were obtained within this operator specified scan time. The acquisition of 15 – 19 slices involved an eight-excitation spin echo pulse sequence, using an 8 mm slice thickness and a 2mm interslice gap. This 35 cm cephalocaudal coverage of the entire liver was performed in a breath-hold scan time of 18 sec. In all patients, image registration was ensured by instructing patients to breathe in a reproducible manner, and all imaging was done at end-expiration. All images were displayed within 30 sec of the end of each scan, and image reconstruction was thus very rapid.

**Image Analysis**

Eight-shot EPI images of 18 focal hepatic lesions in 17 patients were retrospectively analysed. We included two focal hepatic lesions in one patient with both hemangioma and simple cyst. Pathologically and clinically, nine hepatic lesions were shown to be hemangiomas, four were hepatocellular carcinomas, and one was a peripheral cholangiocarcinoma; two cases involved metastasis and two were simple cysts. The hemangioma and simple hepatic cysts were confirmed by clinical follow up, while solid lesions were pathologically characterized as follows: four hepatocellular carcinomas by needle biopsy in three cases, and a significantly high level of alpha feto protein in one case. One cholangiocarcinoma was demonstrated by needle biopsy plus clinical data, and two metastases by needle biopsy plus the presence of primary foci. All pulse sequences except nine unenhanced FMSPGR, obtained as coronal images, were obtained as axial.

**Table 1. Quantitative Assessment of Liver SNR, Spleen-to-Liver CNR, and Lesion-to-Liver CNR in 18 Lesions**

<table>
<thead>
<tr>
<th>Sequences</th>
<th>Liver SNR</th>
<th>Spleen-to-Liver CNR</th>
<th>Lesion-to-Liver CNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPI</td>
<td>28.3 ± 10.9</td>
<td>23.4 ± 21.6</td>
<td>21.1 ± 16.0</td>
</tr>
<tr>
<td>FMSPGR</td>
<td>42.5 ± 29.5</td>
<td>19.0 ± 23.8</td>
<td>14.1 ± 13.0</td>
</tr>
<tr>
<td>FSE</td>
<td>29.7 ± 13.7</td>
<td>18.6 ± 7.6</td>
<td>47.1 ± 41.0</td>
</tr>
<tr>
<td>SE</td>
<td>49.7 ± 24.5</td>
<td>12.7 ± 8.6</td>
<td>14.6 ± 15.8</td>
</tr>
<tr>
<td>Gd-FMSPGR</td>
<td>64.8 ± 38.3</td>
<td>9.4 ± 8.9</td>
<td>24.6 ± 22.2</td>
</tr>
<tr>
<td>Gd-SE</td>
<td>64.3 ± 39.0</td>
<td>13.3 ± 13.0</td>
<td>15.7 ± 14.1</td>
</tr>
</tbody>
</table>

Numbers are Mean ± standard deviation.

**Table 2. Quantitative Assessment in Solid and Non-solid Lesions**

<table>
<thead>
<tr>
<th>Sequences</th>
<th>Solid Lesions (n=7)*</th>
<th>Non-solid Lesions (n=11)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPI</td>
<td>17.1 ± 18.2</td>
<td>23.6 ± 14.6</td>
</tr>
<tr>
<td>FMSPGR</td>
<td>8.1 ± 4.0</td>
<td>18.9 ± 15.8</td>
</tr>
<tr>
<td>FSE</td>
<td>24.9 ± 10.4</td>
<td>62.7 ± 47.5</td>
</tr>
<tr>
<td>SE</td>
<td>11.4 ± 11.1</td>
<td>16.6 ± 18.4</td>
</tr>
<tr>
<td>Gd-FMSPGR</td>
<td>16.3 ± 14.4</td>
<td>29.2 ± 25.1</td>
</tr>
<tr>
<td>Gd-SE</td>
<td>11.9 ± 11.4</td>
<td>18.2 ± 15.6</td>
</tr>
</tbody>
</table>

Numbers are Mean ± standard deviation.

* Metastases(n=2), hepatocellular carcinoma(n=4), cholangiocarcinoma(n=1)
† Cyst(n=2), hemangioma(n=9)

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images. A gadolinium enhancement study was performed with SE and FMSPGPR. To quantitatively analyse images, operator-defined region-of-interest (ROI) measurements were obtained and signal intensity of the liver and lesion. Standard deviation (SD) was measured for background noise. When there were multiple lesions, only one lesion-representative of the average size, as seen on T2 weighted SE images—was analyzed. In each case, the largest possible ROI was used; noise was measured with an ROI placed in the

Fig. 1. Comparison of (A) eight-shot spin echo EPI (B) T2 weighted FSE (C) FMSPGPR (D) SE (E) Gd-FMSPGPR (F) Gd-SE images obtained in a 47-year-old male with a hepatocellular carcinoma (arrow in FMSPGPR) in liver dome. EPI provide the most grainy images due to low SNR. But the contrast between the tumor and liver is very striking in comparison with other pulse sequences. We could not determine the lesion solid or nonsolid with EPI alone.
corner of the image. These SI measurements were used to determine liver SNR (SI liver/SD noise) and lesion-liver CNR (absolute [SI lesion-SI liver]/SD noise).

Using the non-parametric Kruskal-Wallis test, calculated SNR and CNR values of various pulse sequences were compared.

**Results**

For each six pulse sequences, the quantitative res-
ults of liver SNR, lesion-liver CNR and spleen-liver CNR are shown in Table 1. A quantitative assessment of lesion to liver CNR in solid and non solid lesions is summarized in Table 2. Clinical examples are shown in Figs 1 - 4.

EPI provided the poorest liver SNR(p < .01), but a higher spleen to liver CNR (p < .01) than any other pulse sequences. In lesion to liver CNR, EPI was superior to FMPSPGR, SE, and Gd enhanced SE (p < .01) but inferior to FSE and Gd enhanced FMPSPGR (p < .01).

When assessing the value of CNR for the differentiation of solid and non solid lesions, this proved to be inferior to FSE and Gd FMPSPGR (p < .05). Comparison of lesion to liver CNR for a solid mass showed no statistical significance (p > .05).

With regard to lesion to liver CNR, EPI was always inferior to FSE, which is the only comparable T2WI among the six pulse sequences.

**Discussion**

Although high quality T1 weighted images of the upper abdomen can be acquired during a breath hold using spoiled GRE (gradient recalled echo) sequences (5), dephasing caused by field heterogeneity tends to accelerate the rate of decay of transverse magnetization (T2*), and T2 contrast is thus not obtained with GRE sequences (1, 6). T2 weighted imaging is, however, essential for the detection and characterization of focal liver lesions (7, 8). An inherently long image acquisition time and image degradation (including ghost artifacts and lesion blurring) due to gross physiologic motion are, however, limitations of conventional T2-weighted SE sequences. To decrease motion artifacts with SE acquisitions, a variety of approaches has been adopted, but application of these techniques has been only minimally successful. Recently with the use of improved gradient systems, breath-hold T2-weighted SE sequences can be implemented with shorter interecho spacing, thus allowing the use of a longer echo train, minimizing susceptibility artifact, and reducing image filtering due to T2 relaxation (3).

With regard to EPI, long TE echo-planar MR imaging has been studied for clinical capability. However, with single-shot EPI, resolution is limited due to T2* decay during the readout window (9), because data are collected during free-induction decay, data lines acquired beyond the tissue- T2* decay time contain little signal intensity (6).

Finally it is proposed that EPI can also be obtained using a multi-shot acquisition sequence implemented with conventional gradient coils and gradient amplifiers (4, 10). Gaa, et al (3), however, stated that multi-shot EPI is less sensitive and susceptible than those obtained by breath-hold, FSE. In our study, multi-shot EPI was inferior to FSE T2 weighted images in lesion to liver CNR and liver SNR.

It is known that a potential application of echo-planar pulse sequences is rapid lesion characterization of the basis of T2 calculations. For the classification of lesions as solid (eg, metastasis, hepatocellular carcinoma) or nonsolid (eg, cysts and hemangiomas), a previous study concluded that EPI is very accurate (11). The high accuracy of lesion characterization obtained by the use of EPI is believed to be due to the absence of motion related artifacts, the ability to obtain purely T2-weighted images, and the use of multiple data points to calculate T2 relaxation times. In our study, lesion to liver CNR of multi-shot EPI of nonsolid lesions (cysts, hemangiomas) was superior to FMPSPGR, SE, and Gd-SE. Among six pulse sequences, however, the differences of calculated lesion to liver CNR for solid lesions were proved to be statistically insignificant. It thus appears that multi-shot EPI might be valuable for detecting the presence of nonsolid hepatic lesions. Moreover, because EPI is insensitive to the signal intensity variation caused by the through-plane motion of unsaturated spins, characterization of small lesions smaller than 2.0 cm is known to be useful (11). In this study, however, it was difficult to characterize lesions by using EPI to determine whether a lesion was solid or nonsolid.

The limitations of this study are as follows: first, the included number of cases is rather limited, since a busy practical situation does not always allow us to perform all the variable pulse sequences. Though, further extensive comparative studies for EPI and other pulse sequences should be performed; second, nine cases of FMPSPGR imaging were performed by coronal rather than axial scanning. It was not difficult to obtain CNR and SNR data by coronal imaging but was unnatural to use the naked eye to compare those with axial images.

In conclusion, multi-shot EPI provided the poorest anatomic definition, and SNR was low. Lesion-to-liver EPI contrast was lower than that of FSE or GD FMPSPGR, but was comparable or superior to that of SE, Gd SE and FMPSPGR. To detect the presence of non solid lesions, EPI was valuable, but for lesion characterization, it was less valuable. We therefore concluded that multi-shot EPI is less sensitive and susceptible than FSE.
간내 국소 병변 진단에 있어서 Multi-Shot Echoplanar (EPI)

자기공명영상의 가치: 기존의 자기공명영상과의 비교

목적: 간내 국소 병변의 발견과 진단을 위해 기존에 사용중인 T1과 T2 강조영상의 각종 영상 방법 (Fast spin echo T2WI, Spin echo T1 WI with and without Gd enhancement, fast multiplanar spoiled GRASS with and without enhancement)에 비해 multi-shot T2 강조스핀에코 EPI의 가치를 정량적 분석을 통하여 알아보고자 하였다.

대상 및 방법: 병리학, 또는 임상적으로 전이암 2예, 간암 4예, 담관암 1예, 냉종 1예, 혈관종 9예로 확진된 17명의 환자, 18예의 간내 국소 병변에 대해서 2명의 방사선과 전문의가 후향적으로 분석하였다. T2 강조 multi-shot 스피너 에코 EPI영상은 자료 획득 시간 (data acquisition period)을 여덟번(eight shot)으로 나누어 1회 호흡정지(18초) 동안에 얻었다. EPI와 다른 영상 방법에 대한 정량적 비교는 두가지 관점, 즉 병변의 발견과 특성 진단을 중심으로 하였다. 각 증례당 대표적 국소 병변과 간과의 CNR, 간과 비장과의 CNR, 간의 SNR을 각각의 영상 방법마다 구하여 병변 발견율을 비교하였다. 병변의 특성 진단 (characterization)를 비교하기 위하여 고형 병변 (solid lesion)과 비고형 병변 (non solid lesion)에 대한 각 영상 방법의 CNR을 따로 분리하여 구하였다.

결과: 간의 SNR은 EPI가 6개의 영상방법중 가장 낮았다 (p<.01). 병변과 간 사이의 CNR은 EPI가 FSE, Gd-FMPSPG로보다 낮고, FMPSPGR, SE, Gd-SE보다는 높게 나타났다 (p<.01). 고형 병변 (혈관종, 냉종)에 대한 CNR 비교에서 EPI는 FSE와 Gd-FMPSPG보다 낮고 FMPSPG, SE, Gd-SE보다는 높게 나타났다 (p<.05). 고형 병변에 대한 각 영상 방법의 비교는 통계학적으로 의미가 없게 나타났다. EPI의 간 병변간 CNR은 FSE에 비해 항상 낮게 나타났다.

결론: Multi-shot EPI는 간내 국소 병변의 진단에 있어서 다른 영상 방법, 특히 같은 T2 강조영상인 FSE에 비해 간내 국소 병변의 발견과 진단 가치에 있어서 열등하다. 그러나 FSE 이외의 다른 영상 방법과 비교시 EPI는 낮은 SNR이지만 비교적 높거나 비슷한 간 병변 CNR을 유지하여 병변 발견에 유용하다. 특히 비고형 병변의 발견에 유용하다. 그러나 병변의 특정 즉 고형 병변인지 비고형 병변인지의 결정은 EPI영상만으로는 어려웠다.